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HOW TO MAKE A ONE-HORSE-POWER MOTOR OR DYNAMO

By A. E. WATSON.

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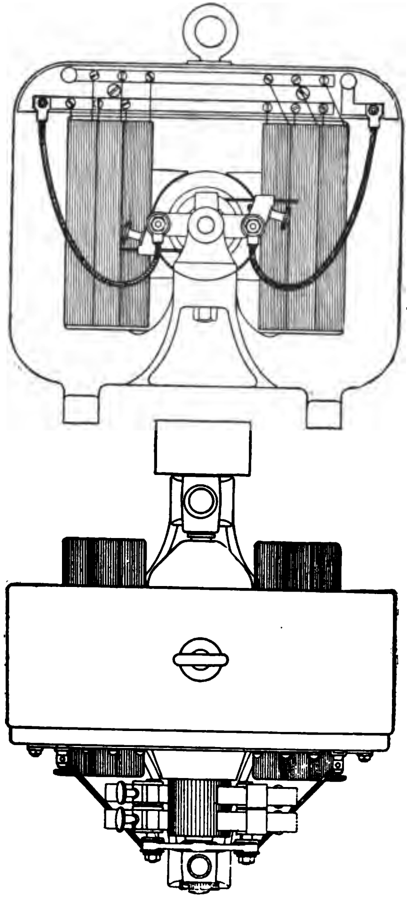

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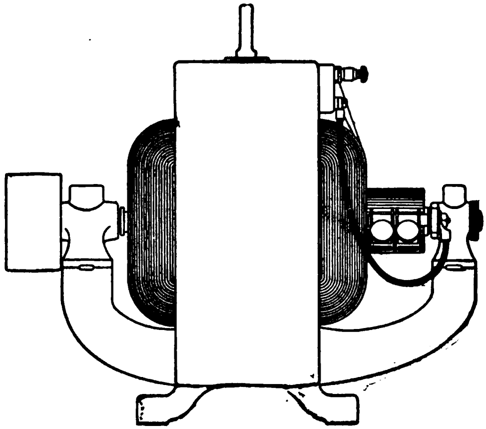

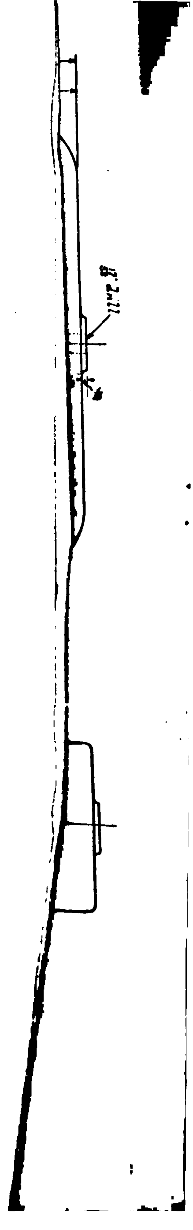

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PREFACE

REPEATED inquiries have been received, calling for description and drawings of a motor or dynamo of one-horse power capacity. On the following pages will be found complete directions for building a practical high speed machine of unique construction. I trust that the builder whether amateur or practical mechanic who follows these directions will be satisfied with his efforts.

A. E. WATSON.

LYNN, MASS., January 1, 1893.

HOW TO MAKE A

ONE-HORSE POWER MOTOR OR DYNAMO.

AN electric motor is capable of appearing in as many different forms as a steam engine. To decide just what form is best adapted for amateurs and other experimenters is difficult to state. As soon as the builder starts, he must decide between a drum or a ring armature, high or low speed, bipolar or multipolar fields, salient or consequent poles; wrought or cast-iron field magnets, iron clad or other forms of magnetic circuits.

The armature may be placed at the top, middle or bottom of the machine. If the constructor were to look in technical papers and books to decide which form to adopt, he would find himself in hopeless perplexity.

In presenting this pamphlet, the writer has had a variety of considerations in mind which were re-

garded as of cardinal importance. Amateurs have limited tool facilities, and in this motor, machine work has been reduced to the minimum. The use of a planer has been completely avoided. A lathe can do all the work. A milling machine will be found convenient, but it is not essential.

The field casting is in but one piece. Even the arms for supporting the bearings are integral with it. The poles are salient, and "end on" towards the armature; the lines of magnetic force do not have to bend in order to go through the armature core. The field coils are nearly covered by the iron, thereby making the wire most useful in producing the magnetism, and the leakage of magnetism is very small.

No exterior magnetism can be felt, and any additional devices for adapting the machine for particular applications, can be bolted to any part of the machine at will. Mechanical joints being absent there is the best of magnetic circuits. Still the field coils can be wound in a lathe upon a form and slipped in position. Winding the field coils in sections allows the wires to be connected for a series motor or dynamo, or in series for a shunt machine.

The armature is in the center of gravity of the machine and protected from danger or damage from the outside. The core is of the ordinary

Siemens' drum type, thus most easily made and wound. The large mass of iron in it and the field keeps the commutator free from sparks. The bearings are very simple and practically self-oiling.

The motor is of one-horse power capacity, will pump water, blow a large organ, run a small machine shop or printing office, will drive a 16-ft. boat, five or six miles per hour. As a dynamo it will run one 2,000 c.p. or two 1,200 c.p. arc lamps, or ten 16 c. p. incandescent lamps, or a sizable plating establishment.

The motor may be belted direct to shafting, or by screwing extra bearings to the frame the speed can be reduced by gearing.

The construction of the field is plain from the accompanying drawing.—Fig. 1.

No attempt has been made to make this a light-weight casting. It weighs a little over one hundred pounds. The efficiency of a motor and the conditions of non-sparking with change of load demand a very powerful magnetic field. It is false economy to begrudge iron for this purpose.

Several ways are possible in making this pattern for the field casting. A good method is to part the rectangular frame on a line even with the lower surface of the pole pieces. The parts for the pole pieces themselves are loose but are to be recessed about half an inch into the frame. By

this construction of the pattern, coring will be avoided, also expense of the core-box, and smoother castings are obtained.

On the ends of the arms where the pedestals for the bearings rest, the middle part is cut away, strips on the inner and outer edges alone receiving machine finish. The bottoms of the bearings, Figs. 2 and 3 are to be treated in the same way. A single bolt through each arm holds the bearings in place.

With the castings at hand, the builder may, if he will, work on the field first. The holes are to be drilled as shown, the four through the legs for bolting to the base board on which the machine is finally to stand. The holes through the ends of the arms are $\frac{}{6}$-in. larger than the bolts, to allow room for adjustment of the bearings. The tapped hole in the top is adapted to receive an eye bolt for convenience in lifting the machine. Two tapped holes on the upper front part of the frame are for holding the connection board in place. Now put the casting in a fairly large lathe and bolt it securely to the travelling carriage: it may be well to remove the tool-post slide from the carriage altogether. With a boring bar between the lathe centers, bore out the fields to the dimensions given.

If the builder has any misgivings about his ability to get the armature winding to its specified

dimensions, he may bore the field $\frac{1}{32}$-in. or $\frac{1}{16}$-in. larger; but he must not forget that the greater the air gap between the polar faces and the armature core, the less the output of the machine.

The ends of the arms for the bearings are to be bored out to the same radius as the fields. Let the final chip be a light one with the holding down bolts somewhat relieved, so that the arms may not be sprung any out of line. Aside from the chipping and filing necessary to remove lumps and burrs the machine work on the fields is now done.

The cast-iron pedestals are shown nearly in full size in Figs. 2 and 3. They are to be held on an angle iron on the face plate of a lathe, or in a chuck, and the holes for the brass linings bored. Mount them upon arbors and turn off the lower surfaces to the same radius as the field was bored. The brass lining for the pulley end is to be drilled from the solid, mounted upon an arbor and the outside turned to fit tightly in the pedestal. A small brass tube through the bottom of the oil cavity will prevent the lining from working out of position.

It will be noticed that the lining for the commutator end bearing is made integral with the brush holder yoke. This is a unique method of simplifying the mechanical construction. In order to insure oil reaching the shaft, whatever be the position of the yoke, a groove should be cut in the

iron around the lining as shown in Fig. 3. A knurled thumb-nut will serve to hold the yoke in any assigned position.

Holes in the bottom of the pedestals are to be drilled and tapped for the bolts that are to secure them in position on the arms of the frame of the machine. At the pulley end a $1\frac{1}{2}$-in. $\frac{1}{2}$-in. 13 hexagon headed bolt is to be used, a $1\frac{1}{2}$-in. $\frac{7}{16}$-in. 14 at the commutator end.

By the construction thus explained and adopted, the builder will see that the bearings will, of themselves, come in line and exactly in the center of the field bore. To take out the armature will require the removal of but one bolt—at the pulley end—when the armature with its pulley and bearing can be drawn out lengthwise, leaving the commutator end bearing with yoke and brushes undisturbed.

The armature with the shaft is shown in Fig. 4. Cold rolled Bessemer steel is suitable for the shaft. Brass retaining heads screwed on the shaft serve to hold the lamination and winding in place. Sheet iron is the proper material of which to make the core, but it is possible to wind the space full between the heads with fine annealed iron wire, soldering it in several places to the heads to prevent slipping. The layers of sheet iron offer an easy path for the magnetism, while through wire

there would have to be a jump from layer to layer.

It will be found well to arrange this part of the work in the following order: If stock for the shaft is of ordinary machine steel, center and turn it to $\frac{11}{16}$-in. its entire length. If cold rolled steel is used the builder can center it so exactly with the aid of the back rest of the lathe that turning will be unnecessary. From the ends of the shaft up to the places where the threads are to be cut, reduce the diameter to $\frac{5}{8}$-in.; cut the threads, 27 per in. for $\frac{3}{8}$-in. further. At the bottom of the threads the diameter will be $\frac{5}{8}$-in. The rest of the turning on the shaft should be reserved until the core is built up, as, on account of the variations in the thickness of the sheet iron, the shaft may be sprung or slightly bent.

By referring to Fig. 1, it will be seen that the width of the field is $4\frac{1}{2}$-in. The length of the lamination of the armature core should be the same. Wrought iron is commonly used for armature heads and forms a part of the magnetic circuit. In this machine the entire core is sheet iron. Brass retaining heads are used, and these are outside the magnetic path. The castings for these heads are hollowed out somewhat on the inside, for lightness and economy of machine turning. They are to be chucked, turned on the flat side, bored and threaded, while in the lathe; or they can be drilled,

tapped, mounted on a nut arbor, and then turned. Three $\frac{1}{4}$-in. holes, as shown, are to be drilled in each head. These are for engaging with the pins of a spanner wrench, when screwing the heads on. Sixteen slots $\frac{3}{64}$-in. wide and $\frac{5}{16}$-in. deep as shown are to be cut in each. These are for holding the winding pegs. This can best be done in a milling machine, but the location for each slot can be marked off carefully, then cut with a hack saw.

Sheet iron .014-in. thick is the standard for armature lamination. Stove-pipe iron is good. The tin-coated iron used in making preserving cans will answer also. The thin layer of tin will not be detrimental. If the builder has difficulty in procuring sheets punched to size, he can buy a sheet of stove-pipe iron and cut it into $3\frac{1}{4}$-in. squares clamp the required number between two metal plates and drill an $\frac{11}{16}$-in. hole through the whole mass. Mount upon an arbor, (do not use the shaft for this purpose), and clamp them together by means of nuts threaded on the arbor itself. Turn to $3\frac{1}{16}$-in. diameter; there will be a saving of time in turning if the sheets have their corners clipped beforehand.

Screw one head on the shaft very tightly, and slide on the punchings until there is just room only to catch the threads of the other head. Screw this to its right position and ascertain if the sheets

are tightly pressed together; if there is room to get a knife in, remove the head and slip on a few more sheets. The shaft can now be put on the lathe, and the core carefully turned to its final diameter 3 in. Finish the brass heads on the outside and turn the shaft itself to the dimensions shown for the commutator, bearings and pulley. Steel shoulder rings are to be forced on as shown, in order to receive the end thrust of the armature when running.

At the pulley the diameter of the shaft is $\frac{1}{2}$-in.; at the bearing $\frac{9}{16}$-in.; for the shoulder ring $\frac{19}{32}$-in.; then to the head it is $\frac{5}{8}$-in. Beside the other head the diameter is $\frac{5}{8}$-in. again, then $\frac{9}{16}$-in. for the commutator, $\frac{17}{32}$-in. for the shoulder ring, and $\frac{1}{2}$-in. at the bearing. The rings are $\frac{7}{8}$-in. diameter and $\frac{1}{8}$-in. thick.

No pulley is detailed, but one 3-in. in diameter with $1\frac{3}{4}$-in. face for $1\frac{1}{2}$-in. belt will answer for a motor. For some purposes, as for driving a boat, for which the motor may be used, a pinion $1\frac{1}{2}$-in. pitch diameter, 1-in. face, 18 teeth can be keyed on the shaft. The gear into which the pinion meshes is to be mounted on the propeller shaft, and a bearing can be screwed on to the bottom of the field casting. Belting should be used wherever possible as any other device wears out the bearings faster and makes more noise. If the machine is

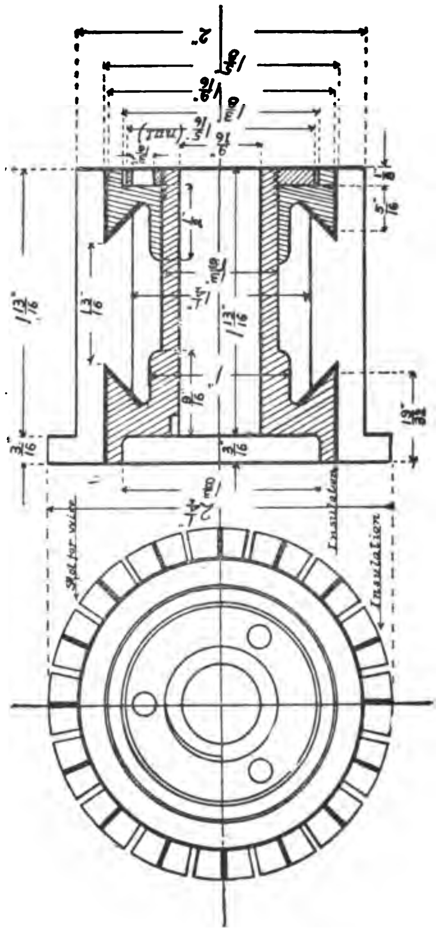

FIGURE 5.

used as a dynamo it will be well to make the pulley 4 inches in diameter.

The construction of a commutator more than any other one part of a dynamo is a Waterloo to amateurs. There is no part requiring better work. Its character directly effects the sparking element of the machine; it is the only expensive part that receives serious wear. It must be very securely made to resist the centrifugal force when revolving. The writer has given up the attempt to get a cheap and durable commutator in one. The remedy was to describe two different commutators, and let the builder make that one which suits his tools and inclination.

The commutator to be first described is the better one. It is shown finished in Fig. 5. The sectional view represents a "sleeve" with flange at back end. This sleeve is bored out $\frac{9}{16}$-in. to fit the shaft. A notch, as shown, is to slip over a pin set in the shaft, to act as a key for preventing the commutator from slipping. The back flange is turned conical at its upper inner edge, and corresponds in shape to the "cap" at the other end of the sleeve. A nut threaded on the sleeve holds the parts together. These conical surfaces grip the segments and hold them securely in position. Either of two methods may be observed for making the segments, 16 in number. A copper cast-

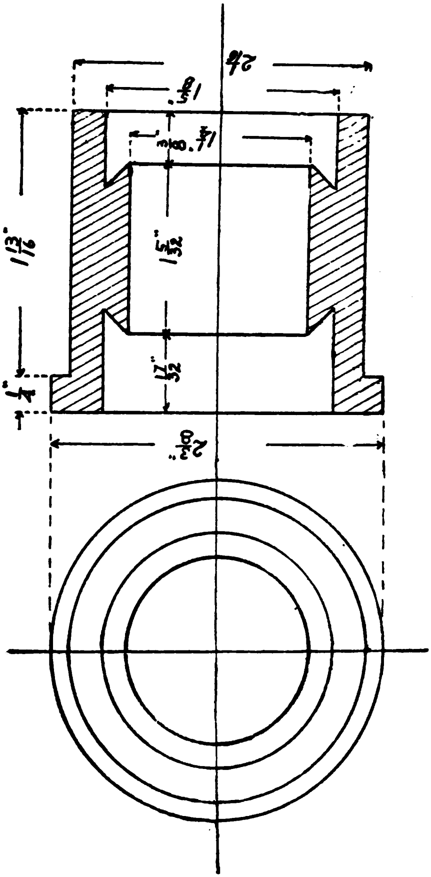

FIGURE 6.

ing in the form of a ring, may be procured and turned to the dimensions shown in Fig. 6. It can then be mounted upon an arbor, and placed on centers in a milling machine. With a saw $\frac{1}{32}$-in. thick, on the mandrel cut the castings longitudinally almost through into 16 parts. Leave about $\frac{1}{32}$ inch of stock at the bottom of the cuts. If a milling machine is not available mark off the location of the cuts in this manner: Take a piece of drawing paper $1\frac{13}{16}$-in. wide and long enough to wrap around the ring exactly. Lay the strip flat, divide it with a pencil into 16 equal parts. Stick this on the ring with shellac, wind string around it and wait a day until it is perfectly dry and hard. Remove the string and with a hack saw proceed to saw exactly on the pencil lines until each of the 16 cuts are almost through the ring. The rim around one edge of the ring is to allow for connecting with the armature winding. Half-way between the division slots cut additional slots through the rim down to the surface of the ring; the wires are to be soldered in these slots.

Fit mica or vulcanized sheet fibre to the division slots and make this insulation conform to the shape of the inside ring. Fit conical rings of shellaced paper $\frac{1}{32}$-in. thick to the tapering surfaces. Now cut the segments entirely apart and then set them up separated each from the other by the insula-

tion. Put the flanged sleeve through, slide on the cap, and screw up the nut by means of a spanner wrench. The commutator can then be laid aside until the armature is wound.

The other method of preparing the segments is to have them cast separately in the first place. Such an unfinished casting is shown in Fig. 7. A metal pattern, with the angle pretty excat, should

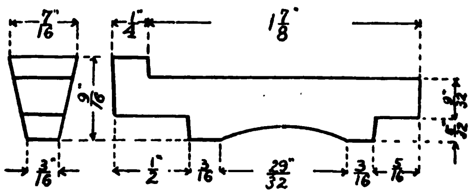

FIGURE 7.

be made. The 16 castings should be filed until they will set up tightly into a complete circle. Shellac a small piece of drawing paper on both sides of each segment flush with the lower edge. After these are dry, shellac the outside of the papers and set the segments up in a circle around an arbor. A short piece of steam pipe should have been previously prepared with 32 set screws, two for each segment. This is slipped over the whole and squeezed together by means of the screws. The arbor in the center compels them to be kept in a circle. If any looseness shows itself between

the segments, more insulation should be placed between them. Make sure that the segments are very tightly pressed together. Yet the arbor must also be held tightly to allow for the lathe work. The central portion only of the arbor, where the segments touch will be about $1\frac{1}{4}$-in. in diameter. Each side of that, the diameter should be $\frac{5}{8}$-in. to allow for reaching the segments with the turning tool. (See Fig. 8.)

Turn out the conical surfaces as shown in Fig. 6. Carefully drive out the $1\frac{1}{4}$-in. arbor. Insert the conical paper insulations, put in the sleeve, cap, and screw up the nut. Loosen the set screws, remove the piece of pipe. Mount the commutator upon a $\frac{9}{16}$-in. arbor and turn the outside smooth. Saw the slots for the wire connections. This latter method is the principle of construction adopted by manufacturers of standard dynamos and motors.

To make the simple commutator shown in Fig. 9, the builder must get a block of vulcanized fibre about 2-in. long and $2\frac{3}{4}$-in. in diameter. Drill a $\frac{9}{16}$-in. hole through the center and turn the outside down true. In one end turn a circle $1\frac{7}{8}$-in. in diameter only deep enough to serve as a mark. Divide this circle into 16 equal parts and prick-punch each. Drill lengthwise through the block with a small drill at each of these spots, and finish with a drill $\frac{5}{16}$-in. in diameter. (It will be best to make

FIGURE 8.

a steel templet with 16 holes, besides the $\frac{9}{16}$-in. centre hole. Clamp this on the block and drill according to the templet. There will then be no chance of the drill running out of line). The holes when finished should have less than $\frac{1}{16}$-in. of stock between them. It will be nesessary to put a brass or steel rim on each end of the block, as shown, in order to ensure the block from cracking. Brass or copper rods $2\frac{1}{8}$-in. long are to be driven into the holes letting one end come flush with the block. Slot the protruding ends radially with a hack saw for the wire connections. Now mount in a lathe, finish the ends smooth and turn down, between the rings, through the fibre to 2 inches in diameter. Each rod will then present a circular face insulated from all the others and contribute towards making a serviceable commutator. As the commutator wears the segments will seem to get closer to each other until the diameter reduces to $1\frac{7}{8}$-in., then as a center line of the rods is passed the thickness of insulation will increase. When the diameter has worn to $1\frac{3}{4}$-in. probably the brushes will spark disastrously.

The brush holder yoke has already been made as it is a part of the commutator end lining so the brush-holders, brushes, studs, and insulations are in order. These parts are shown assembled in Fig. 10. Each brush-holder consists of three parts,

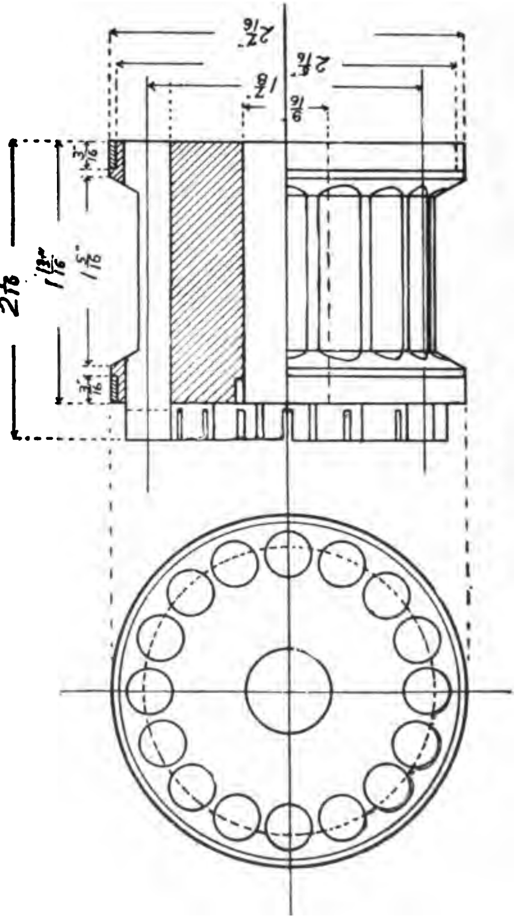

FIGURE 9.

shown detailed in Fig. 11. The body and shoe are brass castings, while the thumb-screws are made of brass rod. The parts can be bright finished all over or left rough as the builder chooses. The brushes themselves are of leaf copper .005-in. thick, laid layer upon layer until a thickness of $\frac{1}{8}$-in. is reached. Then a thicker sheet, say .015-in. is laid on top. The whole mass is to be soldered together at one end, the other beveled, as shown, to fit the commutator. If the commutator first described is built, four brushes can be used, two on each side. Only two brushes can be used, one on each side, with the commutator last described.

In Fig. 11 the studs and insulations are shown. Two studs are to be made. $\frac{5}{8}$-in. hexagon brass rod can be turned to the dimensions given, or $\frac{3}{8}$-in. round rod can be used by driving on hexagon washers to serve as shoulders. The washers should be driven on over the end that is reduced to $\frac{1}{4}$-in. diameter, soldered, and turned off true. The studs are filed flat on one side. By means of the thumb screw the shoe is wedged tightly between the brush-holder body and the stud thus holding the brush and brush-holder in position. More or less pressure of the brushes upon the commutator can be obtained by turning the stud by means of a fork wrench upon the hexagon shoulder. The bushings and washers for insulating the studs are

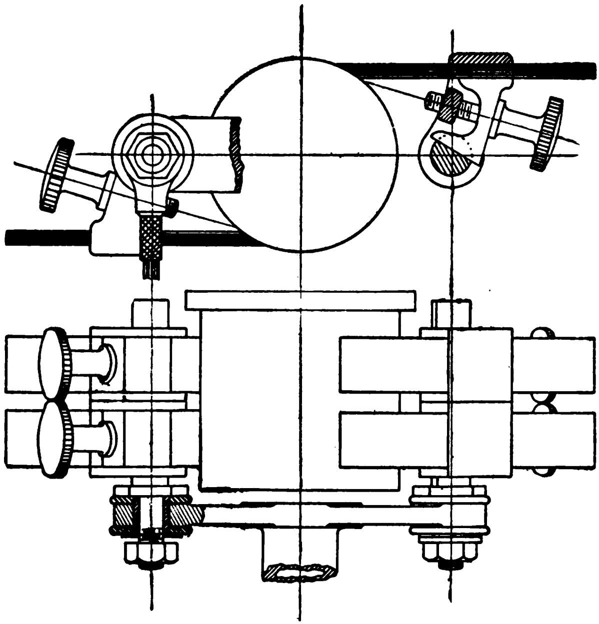

FIGURE 10.

of hard rubber. Brass washers should also be inserted between the nuts and the rubber.

For reversible motors, carbon brushes will be necessary. These are shown assembled in Fig. 12, details are given in Fig. 11. For each holder a strip of copper $\frac{1}{16}$-in. thick is to be bent as shown and a block of soft carbon inserted in the jaw. Immerse the carbon and end of strip in a solution of blue vitriol and, with a battery, plate with copper until the carbon is covered and well joined to the strip. With a piece of emery cloth on a round stick hollow out the carbon, so that they will fit the commutator.

Maple is suitable material for the connection board. If the machine is intended as a series motor or dynamo, the arrangement shown in Fig. 13 is to be used. Binding posts for circuit wires are in the two upper corners. Terminals from the bru-h holder cables enter the other two corners. The current, coming in on one side enters a long brass strip from which it passes to the field coils by wires as shown, back to the other strip and out to the rest of the circuit. On the other end of the board there is simply a straight connection from cable to binding post.

For a shunt motor or dynamo the board shcwn in Fig. 14 is to be used. It will be seen that there is a straight connection through the fuses from

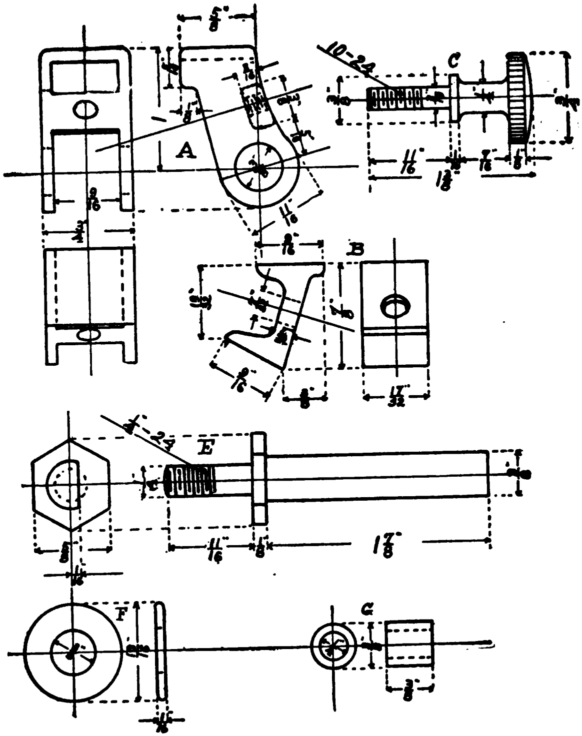

FIGURE 11.

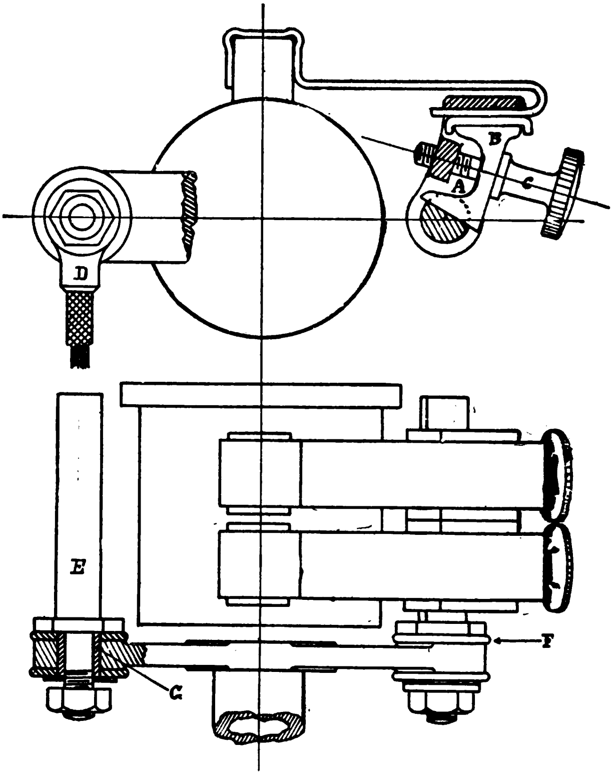

FIGURE 12.

cables to binding posts at each end. The field wires are connected in series with each other and shunted across the terminals. If the machine is used as a motor the two binding posts Nos. 1 and 3 are to be connected by a straight wire ; if as a dynamo these binding posts offer connections for a rheostat for varying the potential. This is usually necessary to compensate for variations in speed and load.

Two $\frac{3}{4}$-in.—14—20 fillister head brass screws will serve to hold the connection board in place on the field magnet. Flexible cables to connect the brush holders with the terminals on the board are necessary.

Incandescent lamp cord will answer if the double strand is used on each side of the machine. A single strand will not be quite sufficient to carry the current. The length necessary and the tips are shown in Fig. 15.

The tips shown are small brass castings, but sheet copper $\frac{1}{32}$-in. thick can be used. By curling one end of a short strip a suitable receptacle for the cable will be given. It is well for the insulation to enter the tips for an eighth of an inch. This prevents unravelling, also supports the wires of the cable so that they are not easily broken.

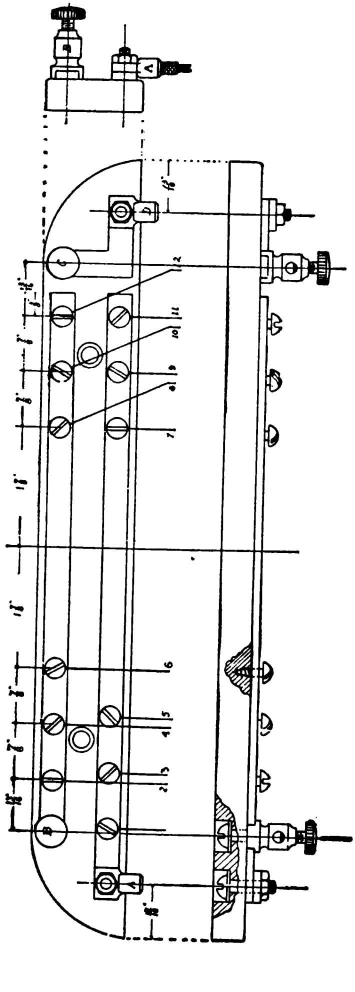

FIGURE 13.

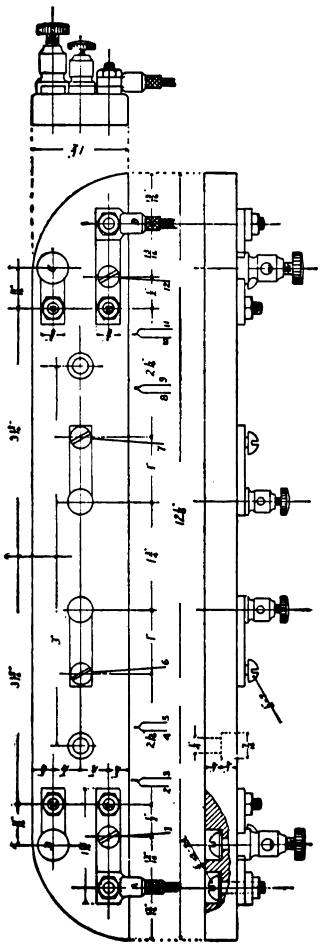

FIGURE 14.

Insulate the armature for winding. Wrap around the shaft four thicknesses of thin paper and two of cloth, well shellaced. Let this extend from close to the heads for about an inch and a half along the shaft. Shellac a disc of thin paper over each of the brass heads; let the paper be large enough in diameter to lap over on to the cylindrical surface of the core; split the edges of the paper to make it lie flat. Wrap one layer of paper around the core itself but this strip should be wide enough only to cover what was not reached by the overlapping paper discs. Put on a second layer that laps over on to the heads. Put small discs of paper over the heads to reach this. A layer of common white cotton cloth can be shellaced on still observing the principle of breaking the joints.

Under no circumstances should a joint come on the edge of the heads. An outside layer of paper completes the insulation. The diameter of the core over insulation should not exceed $3\frac{1}{16}$-in. With a needle feel along the edges of the core until the slots in the heads are found. Cut through the insulation with the point of a jack-knife blade. Drive into each slot a strip of leatheroid or fibre $\frac{3}{64}$-in. thick, $\frac{5}{16}$-in. wide, and leave them sticking out about $\frac{5}{16}$-in.

The insulation and winding of the armature can well be carried on by supporting it between lathe

centers. A more convenient and simple support is shown in Fig. 16. It is made of wood and its construction is too plain to need description. The ends of the armature shaft rest in the semi-circular notches.

Every thing has now been described except the winding itself. The builder must determine what sizes of wire shall be used, by the purpose for which the machine is built. If it is to be used as a motor on a constant potential, or incandescent lamp circuit of 110 volts, certain sizes of wire should be used. If as a series motor on constant current or arc circuit of 10 amperes, other sizes should be used.

Other conditions will necessitate something still different. The method of winding will be the same in all. For purposes of description the following has been selected:

Winding adapted for series motor for 10-ampere arc circuits, or with battery power for running a boat or lathe and few other tools; or as a dynamo for running one full arc lamp or 10 16-c. p. incan descent lamps.

This winding will be for 52 volts potential at the brushes. A current of 13 amperes can safely be allowed. No. 16 (B. & S.) Gauge double cotton covered wire is to be used. Place the armature core in its support and with the spool of wire conveniently arranged, bend the end of the wire so as

to hook around one of the pegs. It may be tied to the peg if need be. With one hand carry the wire along the surface, in between two pegs at the other end of the core. With the other hand turn the core one-half a revolution so the wire will be laid across the end between the two pegs directly opposite. Do not pull it tightly against the shaft, but let there be a space of about $\frac{1}{4}$-in. Bend the wire over the edge and back along the core to the other head, then with another half turn of the

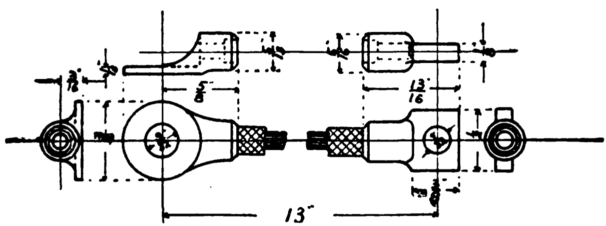

FIGURE 15.

core backward return to the starting point. The same space should be allowed between the wire and the shaft as on the other end; keep on with the wire along side the first turn until another is placed. The space between the wire where it crosses the heads and the shaft will be getting less with each successive turn until five turns are placed. The last turn should wedge in tightly. Pass the next turns on the other side of the shaft.

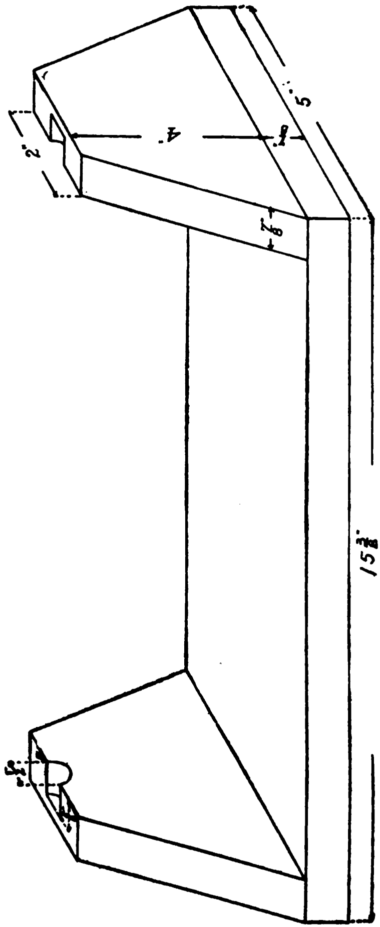

FIGURE 16.

The winder will find that he must rotate the core the other way as each successive half turn is placed. Let these turns be close to the first wires but tight against the shaft. There will be room for only four turns on this side of the shaft. Do not cut the wire when the entire space between the pegs is filled but make a loop about 3-in. long, twisting it together until the continuation of the wire points straight across the head. Figure 17 shows the first coil all wound, also where the beginning and end is. Lead the wire into the space alongside the first coil. To do this, it will of course be necessary to cross the first coil diagonally. Be sure to let there be kept a distance of $\frac{1}{4}$-in. from the shaft as before, so as to leave room for the following turns. Put on the five turns on that side of the shaft, then four on the other side and the second coil will be wound. Bring out a loop, twist it together as before and proceed to cover the space between the next pegs. Pull the wire tightly when possible and always straighten it carefully with the fingers as each turn is laid on. The same order is to be observed for winding eight coils. There will then be eight loops left out for connection with commutator segments. However, there are sixteen segments. How are connections for these to be provided for? For a ninth coil start a turn of wire directly on

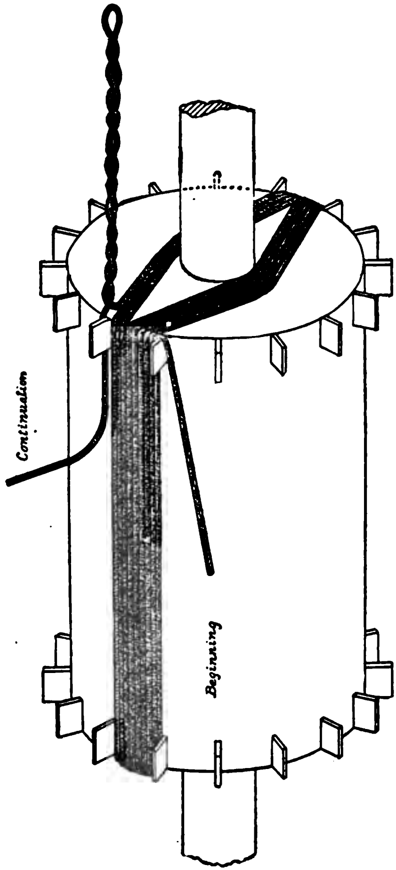

FIGURE 17.

top of the one wound at the very beginning. Put a complete layer on as if there were no winding already there. It will be noticed that on that side of the shaft where in the first layer there were only four turns, five will appear in the second layer, and four in the second on top of the five of the first layer. So the winding is balanced. The second layer over the entire surface will make eight more loops for connections. No cut is to be made in the wire at any time, until the winding is completed when the last and first ends are to be twisted together. Thus the armature circuit is one continuous winding with connections allowable at 16 different places. Shellac the whole very thoroughly. Fig. 18 shows the armature at this stage of construction. Cut off the extra insulation on the shaft beyond the winding and slip the commutator in place.

If the machine is to be used for general purposes as dynamo or motor, and running in either direction, the loops from the armature winding should be led straight to the nearest segments. Scrape the insulation from the wires where they enter the slots in the commutator and solder each carefully. Both wires comprising a loop are to be soldered to the same segment, and the superfluous ends cut off. It will be seen that the end of one coil and the beginning of the next is unbroken.

FIGURE 18.

With the connections made straight like this, the position of the brush-holders and yoke, when the armature is running, will be about horizontal provided carbon brushes are used. With copper brushes the yoke must be tilted to an angle of 45°. It will be possible to allow the yoke to be horizontal, simply for looks, by giving the connection wires from the armature to the commutator a "lead." Instead of connecting a given loop with the nearest segment, carry it to the second segment to the right or left depending on which direction the machine is to run. The other loops follow in order, giving the appearance that the commutator had been twisted out of position one-eighth of a turn.

"Binding" wires will be necessary to hold the copper conducting wires in place. Around each end of the core next to the protruding pegs and in the middle wrap two turns of thin drawing paper, well shellaced. Mount the armature in a lathe, and with the back gears in use wind tightly No. 25 German Silver or brass wire on over the paper bands. The beginning of the wire can be secured to an armature lead wire. After one band has been covered make a quick reach to the next without cutting the wire. Solder the binding wires very securely together. There is no objection to soldering them all the way around. Resin should

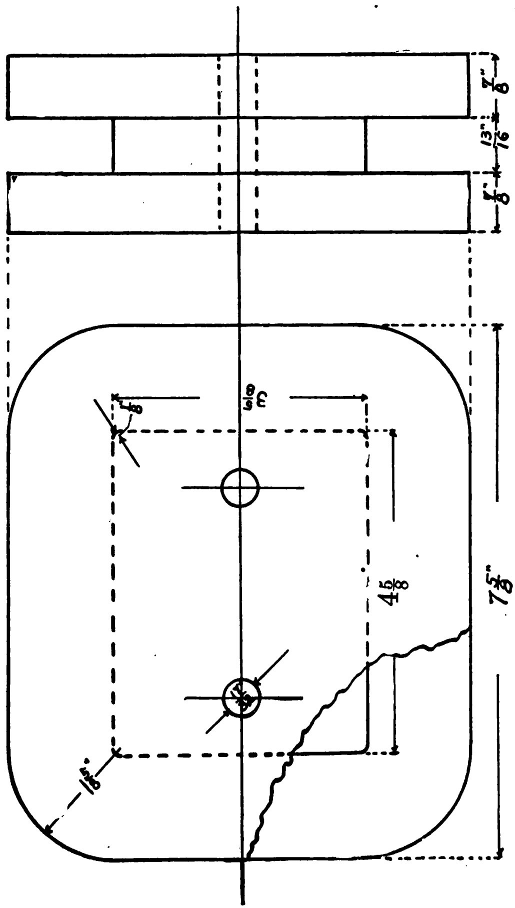

FIGURE 19.

be used as a flux in soldering electrical work as acid is apt to rust the joints.

The lead wires to the commutator can be covered with a conical sleeve of duck well shellaced. Bind the cloth in position by winding strong linen thread around it where it laps on to the armature and commutator.

Clean the shaft from all shellac, slip on the pulley end bearing, put on the pulley, drive in the key, and the armature awaits the field winding.

An armature winding has been selected and described best fitted for general work. The field can also be made to accommodate itself to several conditions. The coils are to be wound in sections slipped on to the pole pieces, and then connected in multiple or series according to the particular application.

The builder has a choice of the size of wire he may use. The amount of energy absorbed in the field, is a large factor in determining the commercial efficiency of the machine.

To excite the field sufficiently to generate 52 volts requires about 5000 ampere turns. This can be accomplished with a total of 2,200 turns of No. 18 wire, and for a shunt machine allowing $2\frac{1}{4}$ amperes of current to flow. On each field core are three separate coils all connected in series. On the connection boards the ends of the six coils are

shown by figures; the odd numbers indicate the outside ends, while the even numbers refer to the inside ends. Fig. 14 for the shunt connection board shows the coils connected in series with each other. Fig. 13 for the series board shows them connected in multiple, making the total resistance of the field $\frac{1}{36}$ as much as in the other case.

Fig. 19 shows the "form" to be used for winding the field coils. It is made of maple and bolted to the face plate of a lathe. Wrap two thicknesses of thin brown paper strips around the center piece.

Do not shellac it but begin winding the wire tightly, let the end of the wire be held in a hole through one of the side blocks. It is well to run the lathe slowly, even to use the back gears. A thin maple strip held in one hand is convenient to crowd the wire into position. As each layer is put on it should be shellaced and one thickness of thin brown paper laid on and again shellaced. The paper will make the layers even, and with the shellac bind the whole so together that it may be removed from the form without injury. Hammer the wire to keep it from bulging up in the center. With the best of precautions however it will measure more across the middle than at the ends. About 23 layers should be put on with 16 turns per layer.

The bolts which hold the form to the lathe, also

hold the parts of the form together, so it is an easy matter to take off the side pieces when a coil is wound. The center block can be driven out as the unshellaced paper that was put around it in the beginning will allow sufficient slipping.

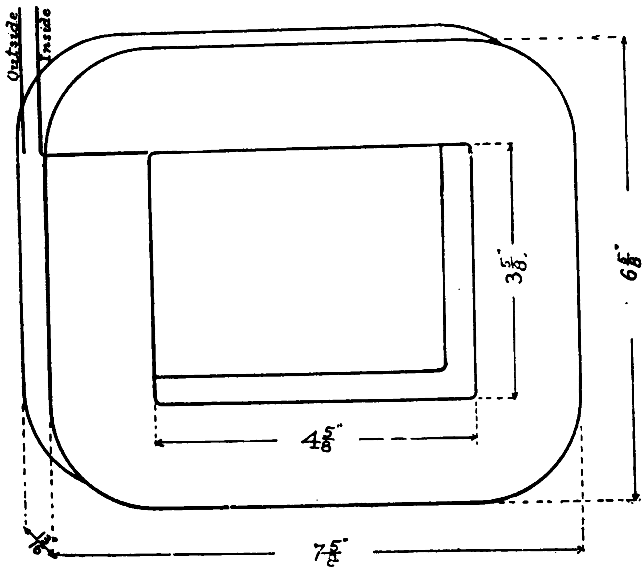

FIGURE 20.

The ends of the coil should be wound with a a little thin paper and the whole coil bound together by wrapping cotton tape all about it. Each coil will weigh about $3\frac{3}{4}$ lbs.

A complete coil is shown in Fig. 20. Paper should be wound on the pole pieces before slipping the coils in place. The coils can be held in position by a few wooden blocks or wedges.

The coils can be painted with vermillion shellac and the iron with a mixture of lamp-black and ordinary varnish. The brass parts may be polished. If the directions have been followed the builder will have no trouble in getting the machine to run as a motor. If he intends it as a dynamo, the fields must have some initial magnetism put into them. This can be easily done with a few cells of a battery connected to the field coils.

If the dynamo is series connected, the main binding posts, B and C are to be short circuited by a wire. If the dynamo will not generate, after moving the brushes slowly back and forth, excite the fields with the battery, so that the poles will be reversed. The machine should then generate.

A shunt dynamo is usually sluggish in starting or " building up " as it is called. Connect the two small binding posts with a short wire, but have no connections leading from B and C. Excite the fields. and coax the machine for a few minutes, by shifting the brushes slowly. If unsuccessful, reverse the polarity and the machine should generate. Do not let the brushes spark.

It will be found that the proper speed for the

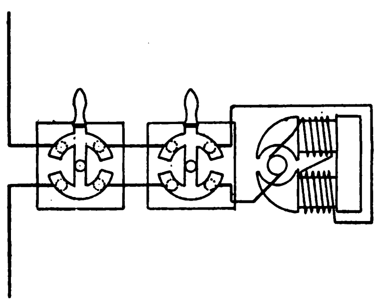

FIGURE 21.

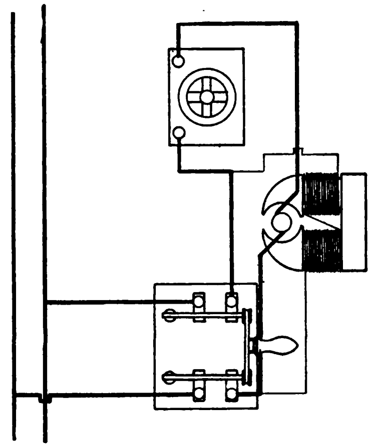

FIGURE 22.

machine is from 2,600 to 2,800 revolutions per minute, depending on the quality of iron used and the care in construction. The machine can be wound for 110 volts if desired, by using No. 20 wire on the armature four layers deep in all, and No. 22 on the fields.

If used as a motor on arc circuits, a suitable centrifugal governor must be used to keep the speed constant. The motor should be connected in circuit with double cut out switches as shown in Fig. 21. A series field may also be wound of No. 9 wire using 6 coils as before, each having 11 layers, and seven turns per layer. These coils must be connected in series. This size of wire should be used if the motor is run on arc circuits, with the centrifugal governor arranged to cut out or in the six different coils one at a time.

As a shunt motor it should be arranged as Fig. 22, with a starting rheostat in the armature circuit.

If the builder desires to wind the machine for 220 volts, the commutator should be made with 32 segments instead of 16. Extreme care should be used with the insulation for 220 volts.

An amateur is warned to desist from any attempt to make a motor for 500 volts; aside from the difficulty of getting insulation to withstand such a pressure, the expense of the necessary fine wire is beyond the resources of beginners.

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